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14. ABSTRACT
This paper presents a study to evaluate the mechanical properties of commercially available GRP composite fasteners for the fairing band assembly components of the hull mounted sonar domes on Canadian frigates. The study was undertaken as part of an effort to develop an all-composite fairing band assembly for a stainless steel sonar dome, to eliminate corrosion problems that occur with the use of stainless steel bolts which result in loss of the fairing band assembly at sea [1]. The assembly consists of two bands and a tail-cap which were changed from stainless steel to GRP composite material. The stainless steel bolts used to fasten the fairing band assembly to the mild steel ship hull were replaced with GRP fasteners to eliminate the corrosion of the mild steel structure [1]. The experimental investigations performed to evaluate commercially available GRP fasteners and the application of the bolts are presented in this paper.

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Evaluation and Application of GRP Composite Fasteners for Sonar Dome Components

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ABSTRACT

This paper presents a study to evaluate the mechanical properties of commercially available GRP composite fasteners for the fairing band assembly components of the hull mounted sonar domes on Canadian frigates. The study was undertaken as part of an effort to develop an all-composite fairing band assembly for a stainless steel sonar dome, to eliminate corrosion problems that occur with the use of stainless steel bolts which result in loss of the fairing band assembly at sea [1]. The assembly consists of two bands and a tail-cap which were changed from stainless steel to GRP composite material. The stainless steel bolts used to fasten the fairing band assembly to the mild steel ship hull were replaced with GRP fasteners to eliminate the corrosion of the mild steel structure [1]. The experimental investigations performed to evaluate commercially available GRP fasteners and the application of the bolts are presented in this paper

INTRODUCTION

This paper presents a study to evaluate the mechanical properties of commercially available GRP composite fasteners for the fairing band assembly components of the hull mounted sonar domes on Canadian frigates. The study was undertaken as part of an effort to develop an all-composite fairing band assembly for a stainless steel sonar dome, to eliminate corrosion problems that occur with the use of stainless steel bolts which result in loss of the fairing band assembly at sea [1]. The fairing band assembly is used to wrap around the dome-hull interface in order to provide a smooth surface, to reduce turbulence and flow-noise. The assembly consists of two bands and a tail cap which were changed from stainless steel to GRP composite material. The stainless steel bolts used to fasten the fairing band assembly to the mild steel ship hull were replaced with GRP fasteners to eliminate the corrosion of the mild steel structure [1]. The experimental investigations performed to evaluate commercially available GRP fasteners and their application for the assembly are presented in this paper.

The GRP fasteners were obtained from various suppliers and fasteners of three standard diameters: 6.3 mm, 9.53 mm and 12.70 mm were considered. Tests were performed to determine the tensile, shear and torque properties of each set of fasteners following procedures similar to the ASTM F606 standard. At least three samples were used for each test in order to provide good statistical averages. The details of the experimental setup and the test results are presented. The properties of the 9.53-mm bolts were found to be adequate for fastening the fairing band assembly and were recommended for the application.

EXPERIMENTAL PROGRAM

Fasteners Tested

Several manufacturers of composite fasteners in the USA were contacted in order to obtain information on commercially available composite fasteners (see Koko et al. 1998). Information was obtained from the following suppliers: (i.) Craftech Industries Inc., Hudson, New York; (ii) McMaster Carr, New York; (iii) Textron Aerospace Fasteners, Santa Ana, California; and (iv) Tiodize Co. Inc., Huntington Beach, California. From the information obtained it was obvious that the composite fasteners could not be used for highly loaded components due to torque limitations. Consequently, the decision was made to use the fasteners for lightly loaded components, which were also the components that had the most significant corrosion problems. Materials were obtained from Craftech Industries and McMaster Carr, which had lower priced products. It should be mentioned that fasteners manufactured by Textron Aerospace Fasteners and Tiodize Co. appeared to be of higher quality (see for instance Cherry Textron (1996)) then those manufactured by the companies selected. However, the cost of the materials was a deciding factor because of limited budget. The tests were performed to ensure that the quality of the cheaper materials was adequate for the application.

Table 1 shows the properties of the four fasteners and their designations. All fasteners were made of GRP material. Fasteners A, B and C, having diameters of 6.35 mm (¼"), 9.53 mm (0.375") and 12.7 mm (½"), respectively, had hexagonal socket heads and were obtained from Craftech Industries. Fastener D with a diameter of 9.53-mm (0.375") had a hexagonal bolt head and was obtained from McMaster Carr. Pictures of the four fasteners are shown in Fig. 1.

Tests Performed

Experiments were conducted to evaluate the tensile, shear and torque properties of the different types of fasteners considered in this study. The tests were performed in the *as received condition* and after soaking in water at 50 °C for periods of 24 and 72 hours, respectively. The latter tests were conducted to determine the effects of moisture on the mechanical properties of the fasteners.

The tension tests were performed on the four types of fasteners following the ASTM F606 standard (1995). Fig. 2 shows the set-up for the tension tests. Tests were performed in the "as received condition" as control. Table 2 shows the number of samples tested for each fastener type. The samples were tested in an Instron machine. The load was applied slowly, at the rate of 9 mm/min and the load displacement behaviour was measured by using an extensometer that was connected to a data acquisition system. The tests were terminated after failure of the fastener occurred.

The four types of fasteners were also tested in shear following the ASTM F606 standard (1995). Fig. 3 shows the setup for the shear tests.. Table 2 also shows the number of samples tested in shear for each fastener type. The samples were tested in an Instron machine. The load was applied slowly, at the rate of 9 mm/min and the load displacement behaviour was measured by using an extensometer that was connected to a data acquisition system.

Torque tests were performed using the test fixture shown in Fig. 4 and a torque meter. The torque meter was constructed using a 3/8" drive ratchet extension instrumented with two 90° strain gage rosettes. The bolts were held in the test fixture using steel nut and spacer blocks. The bolts were loaded by hand using a ratchet at a rate of approximately 9 degrees/second. The torque meter was connected to a data acquisition system to record the torque during the tests. As in the two previous cases, tests were performed in the "as received condition", and after soaking in 50°C for periods of 24 and 72 hours, respectively. Table 2 also shows the number of samples tested in torsion for each fastener type.

RESULTS AND DISCUSSIONS

Tension Test Results

The tensile failure loads for the four fasteners under the various test conditions were obtained by taking the average of the failure loads for all the samples in that test condition. The tensile strength was obtained by dividing the average failure load by the nominal fastener cross sectional area. Fig. 5 summarizes the tensile test results, including the effect of exposure to the hot-wet conditions. The tensile strengths of the fasteners range from 45.5 MPa (6.6 ksi) to 88.3 MPa (12.8 ksi), with the 3/8-16 UNC fasteners (Type B) having the highest strengths and the 1/2-13 UNC fasteners (Type C) having the lowest tensile strength values. Soaking the fasteners in hot water does not have any significant effect on the tensile strength properties of the fasteners, for the test conditions considered. Fig. 6 shows a typical load-displacement curve for the tensile tests.

Shear Test Results

The shear failure loads for the four fasteners under the various test conditions were obtained by averaging the failure loads for all the samples in that test condition as described above. The shear strength was obtained by dividing the average failure load by the nominal fastener cross sectional area. Fig. 7 summarizes the shear test results, including the effect of exposure to the hot-wet conditions. The shear strengths of the fasteners range from 29.7 MPa (4.3 ksi) to 51.7 MPa (7.5 ksi). Again, the 3/8-16 UNC fasteners (Type B) had the highest shear strengths and the 1/2-13 UNC fasteners (Type C) had the lowest shear strength values. Also, soaking the fasteners in hot water does not have any significant effect on the tensile strength properties of the fasteners, for the test conditions considered.

Torque Test Results

The torque strengths of the four fasteners under the various test conditions were obtained by averaging the torque capacities of all the samples in that test condition. Fig. 8 summarizes the torque test results, including the effect of exposure to the hot-wet conditions. The torque capacities of the fasteners range from 1.8 Nm (1.3 ft-lb) to 15.9 Nm (11.7 ft-lb). The torque capacities increase with fastener diameter, such that the 1/2-13 UNC fasteners (Type C) have the highest torque capacity. This is an important result because the torque capacity can indeed limiting factor in the design of composite fasteners. Consider for instance the 1/4-20 UNC fastener (Type A). Even though its tensile and shear strengths are higher than those of the 1/2-13 UNC fastener (Type C), its torque capacity is so low that the tensile and shear capacities may not be realized in any design. Soaking the fasteners in hot water does not have any significant effect on the torque capacities for the conditions considered.

Application of the Fasteners

The fasteners have been applied for fastening the fairing band components in non-load bearing situations. In this condition, the fasteners are designed only for nominal shear and tensile loads. The ranges of tensile and shear strengths of the bolts (45-88 Mpa (6.6-12.8 ksi); and 30-52 Mpa (4.3-7.5 ksi), respectively) are sufficient to sustain the nominal loads. However, the limiting factor in the use of the fasteners is the torque capability. It was recommended that the torque applied to the fasteners be limited to about 4.4 Nm (6 ft-lb). The 9.53 mm (3/8") and 12.70 mm (½") bolts were recommended for the application, with the 12.70 mm (½") bolts being the most preferred option, because of its size (easier to handle for divers).

SUMMARY AND CONCLUSIONS

This paper has presented an experimental study to determine the mechanical properties of commercially available GRP composite fasteners. Accelerated testing, involving exposure to hot water was used to evaluate the effect of moisture on the mechanical properties of the fasteners. Fasteners of three standard diameters: 6.3 mm (¼"), 9.53 mm (3/8") and 12.70 mm (½") were tested. The tensile strengths of the fastener ranged from 46-88 MPa (6.6-12.8 ksi); the shear strengths were typically in the range of 30-52 MPa (4.3-7.5 ksi); and the torque capacities range from 2-16 Nm (1.3-11.7 ft-lb). The influence of moisture absorption on the material properties was not significant for the test conditions used in this study. The GRP composite fasteners are being used to fasten none load bearing composite sonar dome components to a ship hull.

ACKNOWLEDGEMENTS

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Koko, T.S., Connor, M.J. and Corbett, C.V. (1997). "Development of a Composite Fairing Band Assembly for A Stainless Steel Sonar Dome". Proceedings of ICCM-11, Gold Coast Australia, pp. I-426 - I-435.

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Table 1: Identification of Fastener Types

PROPERTIES	FASTENER TYPES			
	A	B	C	D
Dimensions*	¼-20 UNCx1	• -16 UNCx1½	½-13 UNCx1½	• -16 UNCx1½
Head Type	Hex Cap Screw	Hex Cap Screw	Hex Cap Screw	Hex Bolt Head
Material System	40% Long Glass Epoxy	40% Long Glass Epoxy	40% Long Glass Epoxy	Glass Epoxy
Colour	White	White	White	Black
Unit Cost (1997 US$)**	1.85	2.85	3.4	1.43
Supplier	Craftech	Craftech	Craftech	McMaster-Carr

* Imperial Designations
** Based on minimum order quantities

Table 2: Matrix of Composite Bolt Tests

TYPE OF TEST	TEST CONDITION	NUMBER OF SAMPLES FOR FASTENER TYPES			
		A	B	C	D
Tension	As Received	3	2	4	3
	After 24 hours soaking in 50• C water	2	2	2	2
	After 72 hours soaking in 50• C water	2	-	3	2
Shear	As Received	3	2	3	3
	After 24 hours soaking in 50• C water	2	2	2	2
	After 72 hours soaking in 50• C water	2	-	2	2
Torque	As Received	3	2	3	3
	After 24 hours soaking in 50• C water	2	2	2	2
	After 72 hours soaking in 50• C water	2	-	2	2
Total		21	12	23	21

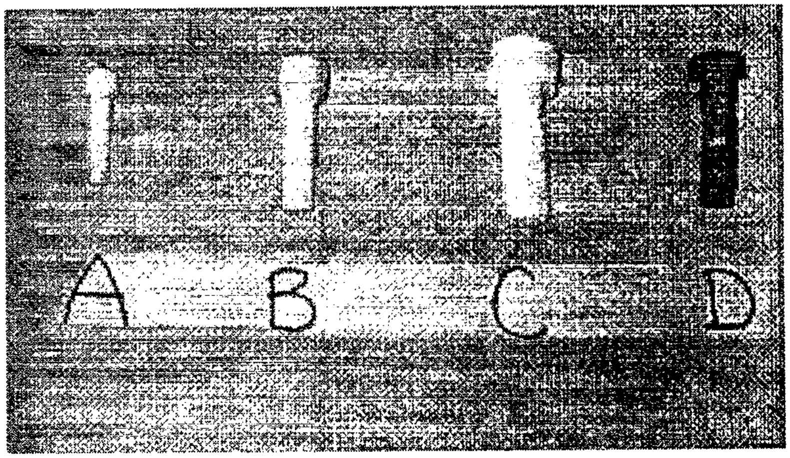

Figure 1: Picture of Failed Composite Fasteners

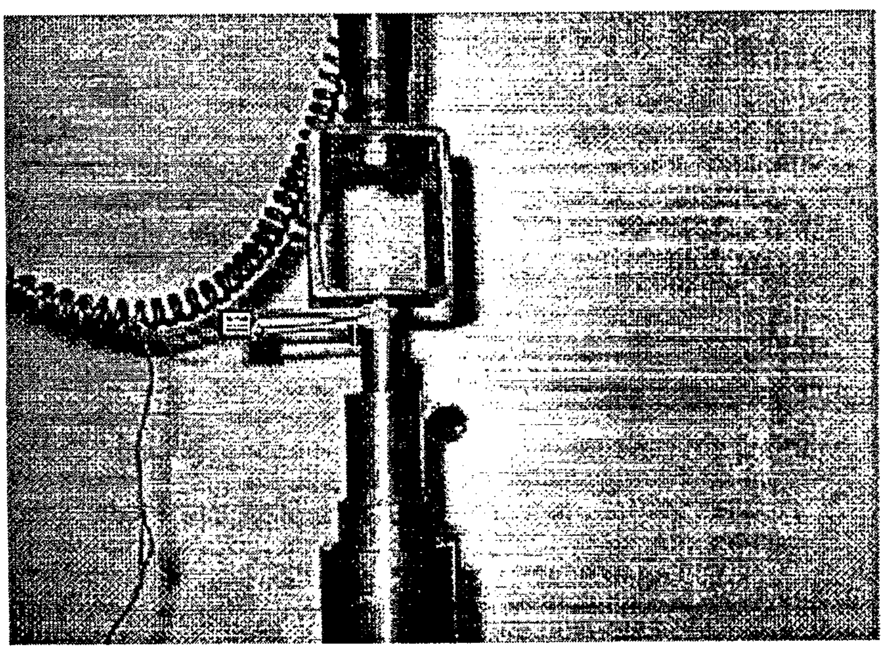

Figure 2 Setup for Tension Tests

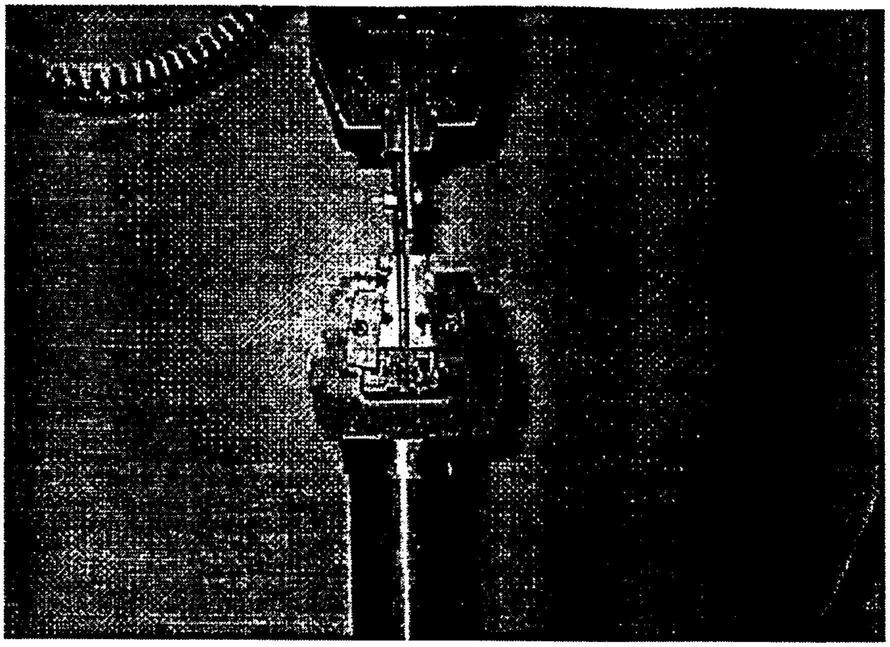

Figure 3 Setup for Shear Tests

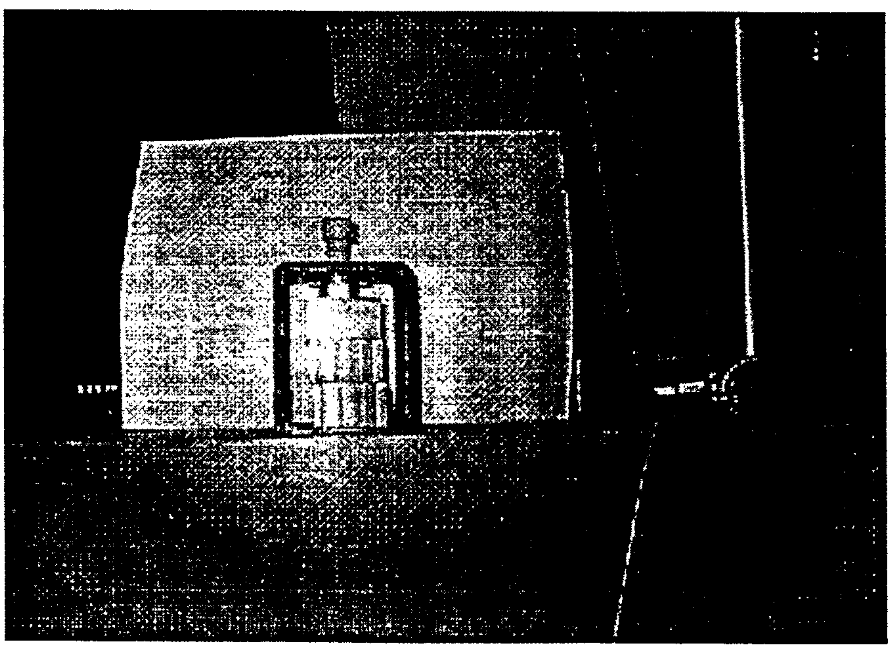

Figure 4 Setup for Torque Tests

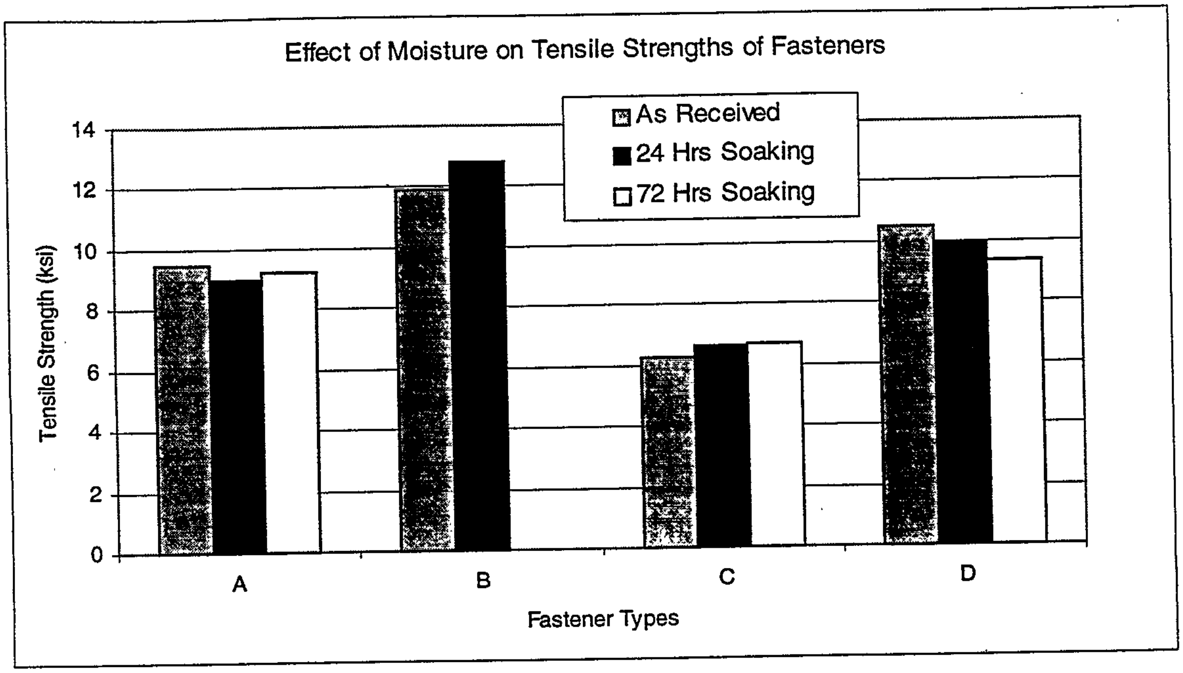

Figure 5: Tensile Test Results

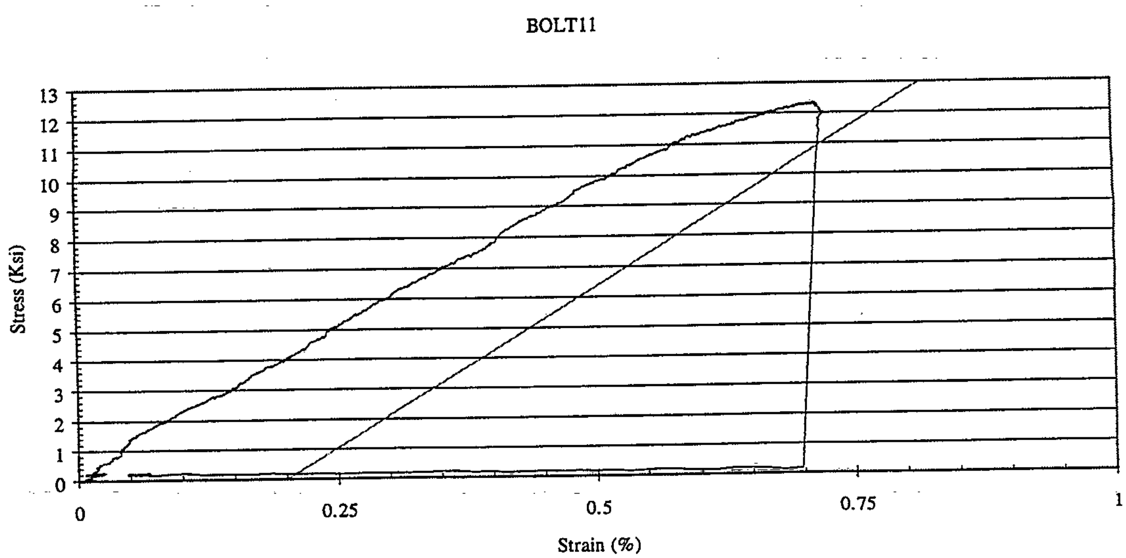

Figure 6: Tensile Load-Displacement Curve of as Received 3/8-16 UNC Fastener

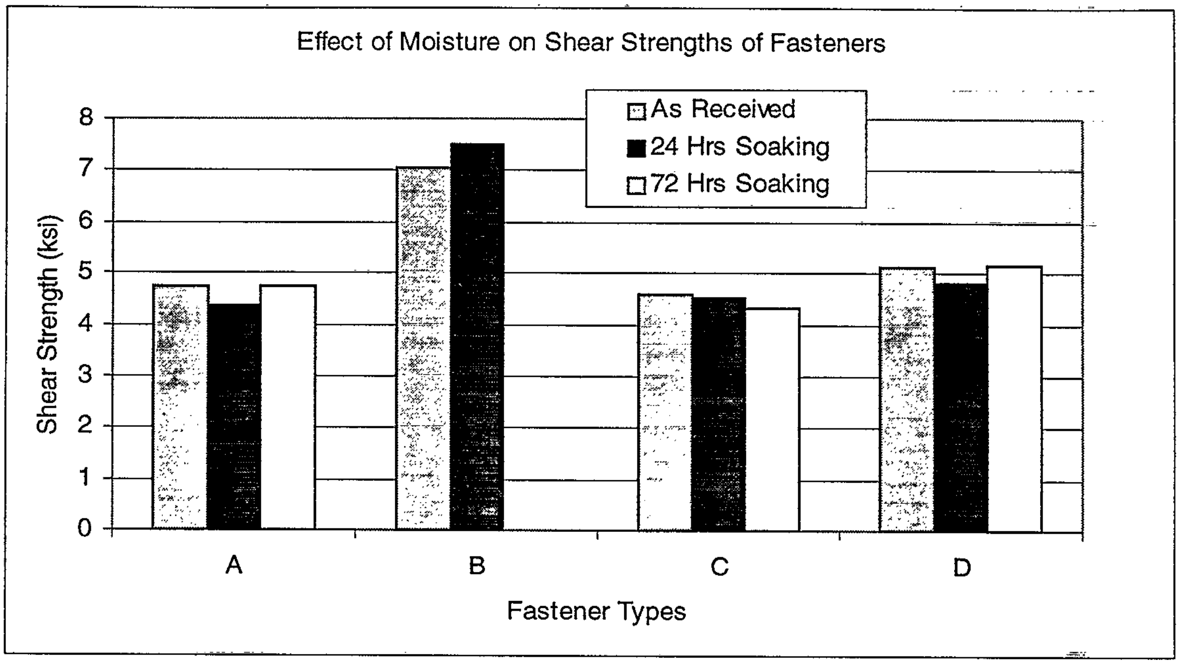

Figure 7: Shear Test Results

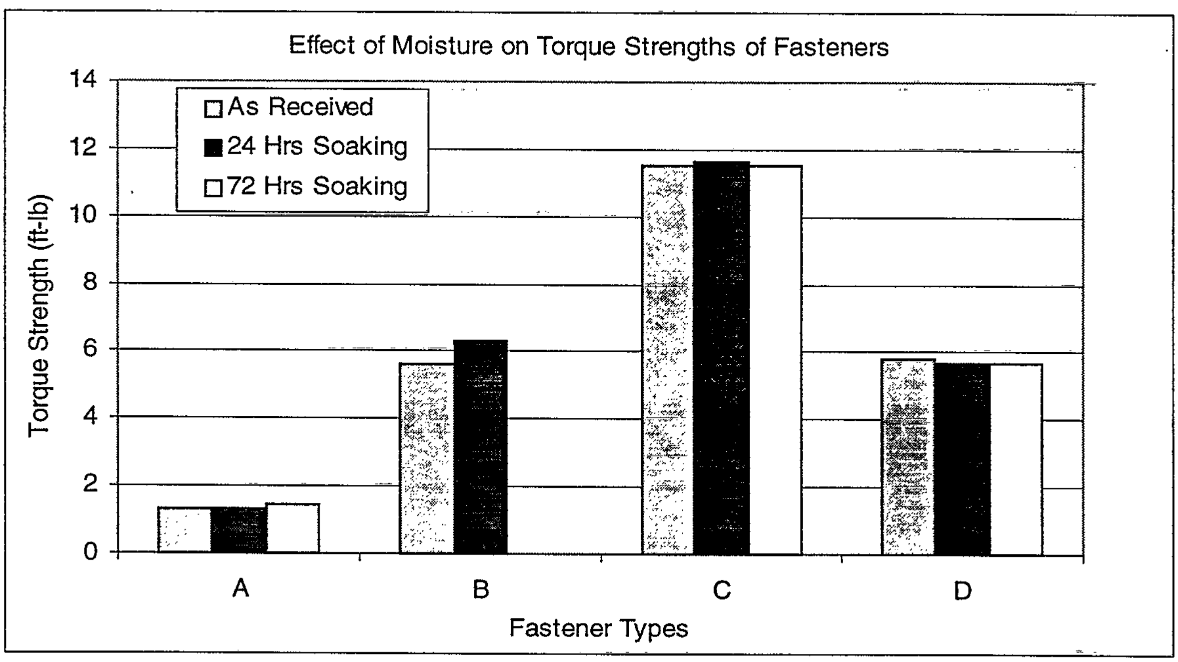

Figure 8: Shear Load-Displacement Curve of as Received 3/8-UNC Fastener